

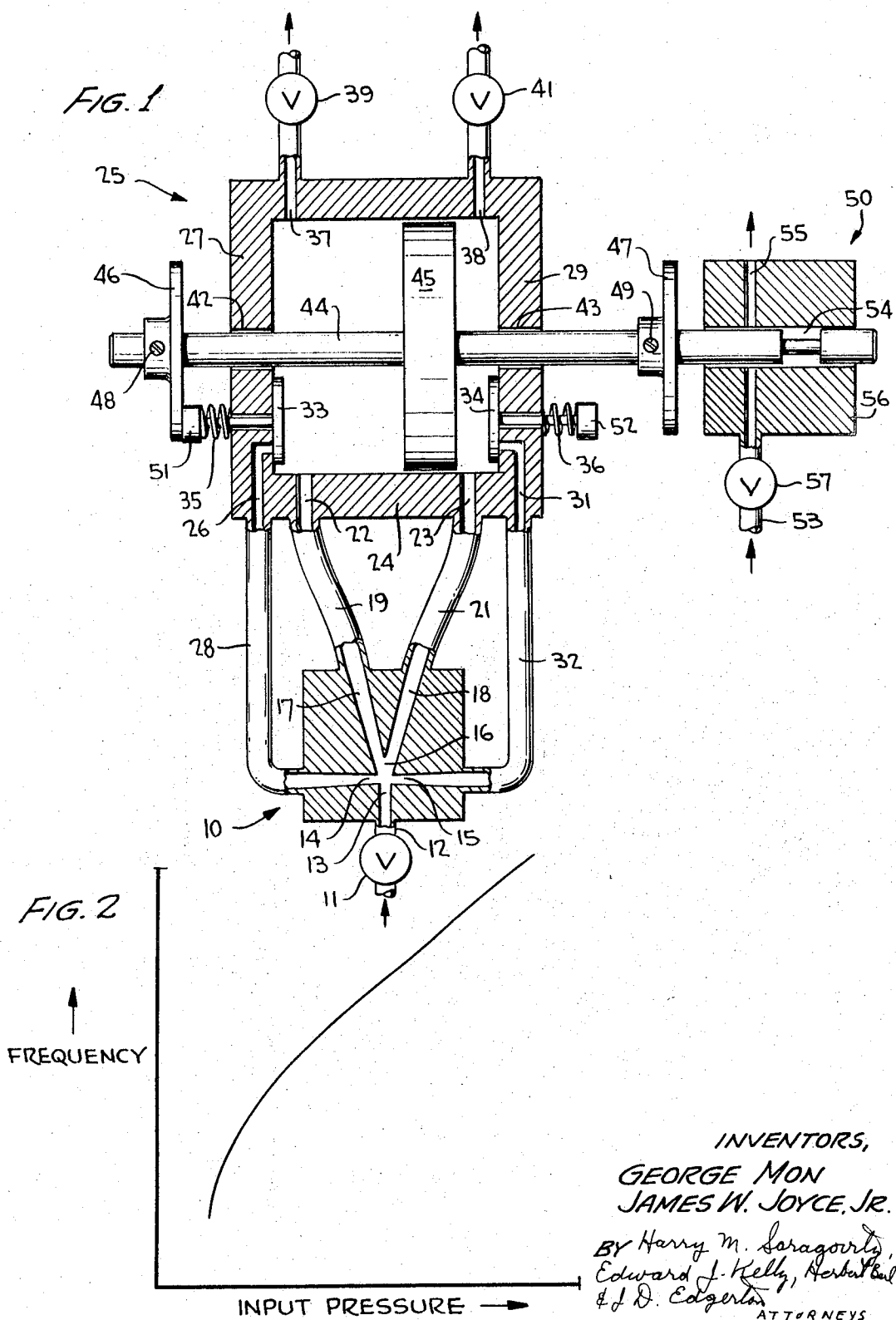
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3,340,896

FLUID AMPLIFIER-DRIVEN OSCILLATOR

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FLUID AMPLIFIER-DRIVEN OSCILLATOR

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ABSTRACT OF THE DISCLOSURE

A pure fluid bistable amplifier has its output conduits connected to opposite sides of a cylinder which houses a piston. The piston has a rod attached thereto and actuating means mounted on said rod, the latter through closure means controlling feedback ports in the cylinder to switch the power fluid in the bistable amplifier from one output conduit to another to make the piston reciprocate.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalty thereon.

The present invention relates to improvements in pure fluid amplifier driven mechanical devices and more particularly to a new and improved oscillating piston operated by a bistable fluid amplifier wherein the switching of the amplifier is accomplished by means of a unique triggering arrangement.

In certain applications it is desirable to have a pure fluid device, such as a bistable fluid amplifier, control one or more mechanical elements. One example of this is in the Membrane Oxygenator disclosed in application Ser. No. 416,937 filed Dec. 8, 1964, by George Mon and Kenneth E. Woodward.

The oxygenator utilizes a gas diffusion process to oxygenate the blood. It has been found that pulsed air flow greatly facilitates the gas diffusion process in membrane oxygenators. Because of the superiority of pulsatile flow compared to steady flow in this process, there is a need for an extremely reliable gas oscillator for the oxygenator.

Pure fluid oscillators, i.e. oscillators having no moving parts except for the fluid itself, can produce the desired outputs by the use of various types of feedback in conjunction with a bistable fluid amplifier. These types of oscillators are now well known in the art. However, they have been found to be extremely load sensitive.

A more reliable unit for producing the desired pulsating output is the bistable fluid amplifier driven, oscillating spool valve arrangement described in the Fluid Oscillator patent No. 3,124,999, granted to K. E. Woodward. In the Woodward oscillator, the outputs of the amplifier are connected to the opposite ends of a power piston enclosed in a cylinder which in turn operates a spool valve. Switching of the power stream of the amplifier alternately to the outputs is accomplished by the piston selectively uncovering ports in the cylinder wall that are connected to the respective controls of the amplifier. Although this unit has performed satisfactorily, it too is load sensitive to a certain extent in that as the axial loading on the piston increases, premature switching of the amplifier will occur due to leakage of pressurized fluid past the piston to the covered port. This problem can be overcome by providing more effective sealing between the piston and the cylinder wall to prevent a spurious fluid signal from reaching the port. However, this is expensive and tends to produce a sluggish movement in the piston when operating under the relatively low power jet pressures normally encountered in pure fluid systems. In addition, this type of oscillator has not been found to be entirely suitable

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where variations in the frequency of oscillation and stroke duration are required, since this must be done either by changing the length of the piston and/or varying the distance between the ports.

5 An object of this invention therefore, is to provide a pure fluid amplifier driven oscillator that is relatively insensitive to load.

Another object of the invention is to provide a pure fluid bistable amplifier driven oscillator wherein the switching of the amplifier does not rely on the piston uncovering a port.

A further object of the instant invention is to provide a pure fluid amplifier driven oscillator wherein the piston and rod assembly offer extremely low friction losses.

15 Still another object of this invention is to provide a pure fluid bistable amplifier driven oscillator whereby the frequency of oscillation is a function of the input pressure of the amplifier.

Yet another object of the present invention is to provide a pure fluid bistable amplifier driven oscillator and sliding spool valve arrangement for producing pulsatile fluid flow wherein the waveform of the pulsatile flow may be easily varied.

20 According to the instant invention, the foregoing and other objects are attained by providing within a pure fluid bistable amplifier driven oscillating piston combination, a cylinder closed at both ends with a loosely fitting piston therein driven by the differential pressure across the piston produced by the fluid output streams of the amplifier. An output channel and a control signal input passage on the same side of the amplifier communicate with one side of the piston through ports in the cylinder wall. The output channel port is open at all times while the control signal port is normally closed by a closure element. When the power stream of the amplifier is flowing in the output, the piston will be moved in one direction until a striker carried by the piston rod actuates the closure to uncover the control port thereby allowing a fluid control signal to switch the power stream to the other output. The piston is then returned by either the fluid pressure from the other output or by some other means.

25 The specific nature of the invention, as well as other objects, aspects, uses and advantages thereof, will clearly appear from the following description and from the accompanying drawing, in which:

FIG. 1 is a plan view, partly in section, of an embodiment of a fluid amplifier driven oscillator and spool valve arrangement constructed in accordance with the teachings of the invention; and

30 FIG. 2 is a graph depicting the frequency of oscillation of the piston as it varies with the input pressure to the fluid amplifier.

Referring now to the drawing, there is shown in FIG. 1 a pure fluid amplifier 10, which is supplied with pressurized fluid from a source (not shown) through an input control valve 11 and line 12 to a power jet producing nozzle 13. Amplifier 10 has a left control jet nozzle 14, a right control jet nozzle 15, an interaction chamber 16, a left output channel 17 and a right output channel 18. Amplifier 10 may be constructed according to any of the methods known to those skilled in the art. Amplifier 10 is preferably a bistable or memory type pure fluid element that utilizes the principles of boundary layer control to maintain attachment of the power jet stream to one of the walls of interaction chamber 16.

35 The output channels of amplifier 10 are connected by means of suitable conduits 19 and 21 to left and right input ports 22 and 23, respectively, in the sidewall 24 of a power piston and cylinder combination generally indicated at 25. A left feedback control port 26 in the cylinder end-wall 27 provides fluid communication between the interior

of the cylinder and left control nozzle 14 of amplifier 10 via tube 28. The opposite endwall 29 of the cylinder is provided with a right feedback control port 31 to conduct fluid signals from within the cylinder to the right control nozzle 15 via tube 32. The feedback control ports 26 and 31 are covered by means of poppet type valves 33 and 34 respectively which are held in a sealing relation with respect to the ports through use of biasing means such as the springs 35 and 36 respectively. A left bleed port 37 and a right bleed port 38 in communication with the ambient are provided in cylinder sidewall 24 at locations that are shown as being approximately diametrically opposed to the left and right input ports 22 and 23 respectively, but which may be located closely adjacent thereto. The flow of fluid entering or leaving the cylinder via the bleed ports is controlled by means of left and right bleed control valves 39 and 41 respectively.

Cylinder endwalls 27 and 29 have a pair of axially aligned openings 42 and 43 which provide bearing surfaces or bushings for a freely reciprocating shaft or rod 44 that is powered by a rigidly mounted disc like piston 45. Both the shaft 44 and the piston 45 are preferably fabricated so as to allow a slight amount of clearance between themselves and their respective bearing surfaces for reasons to be described below. Carried by piston rod 44 exteriorly of the cylinder endwalls are a pair of movably adjustable striker plates 46 and 47 which are held in a particular axial position along the rod by means of suitable locking devices such as the set screws 48 and 49 shown. The striker plates are constructed to actuate the spring loaded valves 33 and 34 when they contact the trigger portions 51 and 52 thereof respectively when the piston reaches a predetermined position in the cylinder.

In the embodiment shown in FIG. 1, the movement of the piston rod 44 is utilized to operate a spool valve assembly 50 which is placed in an oxygen input line 53 in order to provide the desired pulsatile gas flow to a membrane oxygenator (not shown) mentioned above. Piston rod 44 is machined to provide an annular groove 54 which will cooperate with the passage 55 in the spool valve housing 56 to produce the oxygen output flow. An oxygen control valve 57 in line 53 is also provided to vary the gas flow when necessary.

In the operation of the system, opening of the input control valve 11 causes a stream of fluid under pressure to issue from power jet nozzle 13 into the interaction chamber 16. The fluid in this application is air, but other gases or liquids may also be used. If the stream is biased to flow into the left output channel 17, by appropriately designing the bistable amplifier 10 in the ways well known in the fluid amplifier art, pressure will build up in the cylinder on the left side of piston 45, moving the piston and rod 44 to the right as shown, until the striker 46 contacts the valve 33 and uncovers the left feedback control port 46. Opening of the port allows a pulse of air to flow into the left control nozzle 14 to create a pressure differential across the power stream resulting in the switching of the power stream into the right output channel 18. As the flow continues in the right output channel 18, some of the fluid to the left of the piston will be entrained by the power stream while some will escape through bleed 37 with bleed control valve 39 open. The pressure will build up to the right of the piston causing it to move to the left until striker 47 contacts trigger 52 to uncover the right feedback control port 31 and bring about the switching of the power stream into the left output channel 17 in the same manner described above.

Since the piston and rod are connected to a spool valve, the reciprocating motion of the piston changes the continuous input flow of oxygen into a pulsatile output flow. It will be obvious, of course, that the motion of the piston may be adapted through the appropriate linkage to operate other types of valves, or other mechanical elements. Furthermore, the piston and cylinder arrangement may be modified to be single acting or have one power

stroke rather than two if desired. This may be done by merely utilizing one side of the amplifier to provide the pressurized fluid to the cylinder and having the piston returned by a biasing means such as a spring or by employing the entrainment characteristics of the amplifier to "suck" the piston back.

By providing a slight amount of clearance between the piston and the cylinder wall 24 and between the shaft 44 and the bushings 42 and 43 the fluid flow between the surfaces acts as a gas bearing thereby reducing the frictional losses to a great extent. Similarly, clearance around the spool valve may produce the same result when the oxygen valve 57 is open.

The performance of the bistable fluid amplifier-driven oscillator of FIG. 1 can be analyzed by summing up the forces acting on the piston 45 as follows:

$$(P_1 - P_2)A - f = f_1 = Ma \quad (1)$$

where P_1 =pressure on the left side of the piston, P_2 =pressure on the right side of the piston, A =effective area of the piston, f =total friction force acting on the piston, f_1 =loading presented to the spool valve, M =total mass of the piston, and a =acceleration of the piston.

Equation 1 indicates that the acceleration of the piston is directly dependent upon the pressure differential across the piston. Since this pressure differential is directly related to the input pressure of the fluid amplifier, the frequency of oscillation of the piston is a parabolic function of the input pressure to the amplifier. The relation of the frequency of oscillation to the input pressure is graphically illustrated in FIG. 2.

The frequency of oscillation of the piston may also be varied independently of the input pressure by adjusting the bleed control valves 39 and 41. Also, the stroke duration in either direction or both can be changed by appropriate adjustment of the bleeds since they control the rate at which fluid on either side of the piston flows into or out of the cylinder. In addition, the stroke length can be easily altered by changing the location of the strikers 46 and 47 along the shaft. Changes in the frequency of oscillation and stroke characteristics of the piston are used effectively in the present system to vary the waveform of the oxygen output from the spool valve unit 50.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claims.

We claim as our invention:

1. In a fluid amplifier driven oscillator having a piston enclosed within a cylinder and a rod attached to said piston and extending external of said cylinder and being acted upon by the pressure of the stream of fluid supplied to an input port in said cylinder from an output channel of a pure fluid bistable amplifier to produce reciprocating movement of said piston, and including a feedback path for conducting a fluid pressure signal from a feedback port in said cylinder to a control nozzle of said amplifier to switch the power stream of said amplifier into the other output channel when said piston has moved a predetermined distance, the improvement comprising:

- (a) closure means separate from said piston and housed by said cylinder for selectively opening and closing said feedback port,
- (b) said closure means being biased in a closed condition to prevent spurious fluid signals from reaching said control nozzle, and
- (c) actuating means carried by said piston rod cooperating with said closure means to open said feedback port when said piston has moved said predetermined distance.

2. In the oscillator set forth in claim 1, the added improvement comprising:

- (a) bleed means for providing fluid communication between said cylinder and the ambient,

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- (b) said bleed means being adjustable to vary the fluid pressure in said cylinder,
- (c) whereby the operating characteristics of said piston may be changed.

3. The oscillator according to claim 2, wherein:

- (a) each of the output channels of said amplifier supplies power stream fluid to separate input ports in said cylinder,
- (b) each of the control nozzles of said amplifier receives fluid signals from separate feedback ports in said cylinder,
- (c) said feedback ports having separate closure means and actuating means for selectively opening and closing said feedback ports,
- (d) one of said input ports and one of said feedback ports being located in said cylinder to one side of said piston,
- (e) the other of said input ports and the other of said feedback ports being located in said cylinder to the other side of said piston, and
- (f) said bleed means providing fluid communications between said cylinder on both sides of said piston, whereby
- (g) said piston is double acting.

4. The oscillator according to claim 3, wherein:

- (a) said closure means are spring loaded poppet type valves having trigger portions at one end thereof,
- (b) said actuating means including striker means carried by said rod for opening said valves when said striker means contact said trigger portions,

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- (c) said striker means being adjustably mounted on said rod, whereby
- (d) the stroke of said piston is controlled by the location of said strikers on said rod.

5. The oscillator according to claim 4, wherein clearance space is provided between said piston and said cylinder and between said rod and said endwall openings to allow the presence of pressurized fluid in said spaces thereby reducing the frictional losses during operation of said piston.

6. The oscillator according to claim 5, wherein:

- (a) said rod is operatively connected to a spool valve,
- (b) said spool valve controlling the flow of a fluid,
- (c) whereby the reciprocating movement of said piston produces a pulsatile output flow from said spool valve.

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